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Atlantic Salmon Fishery in the Baltic Sea – A Case of Trivial Cooperation

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Abstract This paper analyses the management of the Atlantic salmon stocks in the Baltic Sea through a coalition game in the partition function form. The signs of economic and biological over-exploitation of these salmon stocks over the last two decades indicate that cooperation among the harvesting countries, under the European Union's Common Fisheries Policy, has been superficial. Combining a two-stage game of four asymmetric players with a comprehensive bioeconomic model, we conclude that cooperation under the Relative Stability Principle is not a stable outcome. In contrast, the equilibrium of the game is non-cooperation. The paper also addresses the possibility of enhancing cooperation through more flexible fishing strategies. The results indicate that partial cooperation is stable under a specific sharing scheme. It is also shown that substantial economic benefits could have been realised by reallocating the fishing effort.

Keywords Atlantic salmon, bioeconomic model, coalition formation, partition function, sharing rules, stability analysis

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1 Introduction

The Atlantic salmon of the Baltic Sea is a valuable resource shared by several coastal states. Damming, pollution, overfishing and changes in the Baltic Sea ecosystem have caused a serious decline in the wild naturally reproducing salmon stocks (Karlsson and Karlström 1994). Therefore, in 1997 the now defunct International Baltic Sea Fishery Commission launched the Baltic Salmon Action Plan that aimed to recover wild Baltic salmon stocks. The goal was to reach 50% of the estimated smolt (juvenile salmon) production capacity by 2010. Presently it is expected that only some of the more productive salmon stocks will reach this goal (ICES 2008). To ensure sustainable management of the Baltic salmon stocks, the European Commission have therefore decided to develop a new management framework for Baltic salmon (European Commission 2007).

The salmon fishery in the Baltic Sea is regulated by the European Union's Common Fisheries Policy (CFP) that determines each country’s total allowable catch (TAC). Additionally, each country has its own regulations, for instance regarding the length of the fishing season. The salmon TAC in the Baltic Sea region is shared among the EU countries according to the Relative Stability Principle (RSP) (Council Regulation no. 172/83) that allocates to each member state a fixed percentage of the catch volume yearly available. The total TAC is a result from the political decision process based on scientific salmon stock assessment. Based on the RSP each member state knows the total TAC level required to maintain its own share high enough. Consequently, member states have an incentive to "talk up" the total TAC (Boude et al. 2001). Salmon catches in the Baltic Sea have declined since 1990 from 5600 tonnes in 1990 to 1275 tonnes in 2006 (ICES 2007). Despite the decline in catches, the TAC has been set so high that it does not restrict the fishery. Since early 1990s, the reported salmon catches have been near 70% of the TAC (Aps et al. 2007).

As explained above, CFP sets the framework for the salmon fisheries management according to which all countries harvesting salmon negotiate and agree on TAC annually. However, this framework appears to have failed to achieve CFP's objectives to maintain sustainable salmon stocks and economically viable fishing industries. This failure occurred despite the enormous number of biological (Säisä et al. 2003; Jokikokko et al. 2004; Kallio-Nyberg et al. 2004; Säisä et al. 2005) and management related studies (Karlsson and Karlström 1994; Koljonen et al. 1999; Romakkaniemi et al. 2003; Uusitalo et al. 2005; Michielsens et al. 2008) on the Baltic salmon. Studies addressing the economic dimensions of the Baltic salmon fisheries are, however, scarce (Laukkanen 2001; Laukkanen 2003; Kulmala et al. 2008). The poor state of the salmon stocks in the Baltic Sea and the low catches compared to the TACs raise a fundamental question: does a real cooperative management of the species exists? To answer this question we analyze strategic interactions between the countries harvesting salmon through a coalition formation model.

The earlier studies on the cooperative management of the migrating fish stocks have used characteristic function (C-function) games to address the sharing of cooperative surplus (see e.g. Kaitala and Lindroos 1998; Duarte et al. 2000; Lindroos 2004). Recently, games in the partition function (P-function) form have been introduced in the fisheries literature (Pintassilgo 2003; Pham Do and Folmer 2006). P-function games are able to analyse potential externalities of coalition formation, i.e. the effects that mergers produce on the non-merging players. Fishery games generally exhibit positive externalities, that is, when some fishing states join together in a coalition the other states benefit from it. This generally occurs as the coalition tends to reduce its fishing effort in order to better manage and safeguard a fish stock. The states outside the coalition benefit from those efforts, through an increase in the stock availability. In this context, free rider incentives tend to be present and therefore a grand coalition is rarely an equilibrium outcome (Yi 1997).

The bioeconomic model of the Baltic salmon fishery that we use was developed by Kulmala et al. (2009) and it is based on the state-of-the-art population dynamic model used in the salmon stock assessment (ICES 2008; Michielsens et al. 2008). Kulmala et al. (2009) analysed the two polar management scenarios: grand coalition and non-cooperation. In this paper, we employ the P-function approach, which allows for partial cooperation. This approach is used to analyse characteristics of the fishery game, such as the existence of positive externalities, to determine the stability of all possible coalitions, and the equilibrium of the game.

The coalition formation is modelled as a single-coalition and open-membership game (D'Aspremont et al. 1983). This paper fills a gap in the literature by providing an empirical application of coalition formation in fisheries. In particular, it is directly related to previous theoretical studies such as Eyckmans and Finus (2004) and Pintassilgo and Lindroos (2008). The former proposes a sharing scheme to distribute the gains from cooperation in coalition games with externalities. The latter analyses coalition formation in fisheries using the classical Gordon-Schaefer bioeconomic model (Gordon 1954; Schaefer 1957). In addition, we address the following question raised by Yi (1997): "As hard as the analysis may be, the heterogeneity of players raises the interesting and important issue of the composition of coalitions: do coalitions in a stable coalition structure [...] consist of similar players or dissimilar players or both?" Due to the migration pattern of salmon, the catch of different countries has a different effect on different salmon stocks. Consequently, our detailed analysis of potentially stable coalitions will give insights into the planning and implementation of the forthcoming salmon management plan.

The paper is structured as follows. The next section presents the underlying bioeconomic model. Section 3 defines the game and the stability concepts. In Section 4, we discuss the results from the fisheries policy scenario compatible with RSP. Section 5 presents the results from optimal fishery policies. Section 6 discusses the implications of partial cooperation to the salmon stocks and Section 7 concludes the study.

2 Bioeconomic Model

The underlying bioeconomic simulation model on which we base our coalition game follows Kulmala et al. (2009). The model considers four fishing states controlling around 80% of the TAC and catching 90% of the annual salmon catch: Finland, Sweden, Denmark and Poland. The countries differ from each other in terms of the structure of the salmon fleet, fishing costs, salmon price and harvestable stock size. We review shortly this highly disaggregate and sequential model in those parts that are necessary to understand the present analysis and results.

Figure 1 illustrates the salmon migration routes in the Baltic Sea and Figure 2 the population dynamics model with sequential fishery. The adult salmon recruit mainly to the fishery during their feeding migration to the Baltic Main Basin. There, salmon is harvested by offshore driftnets and longlines which we denote by ODN and OLL, respectively. All four countries participate in these fisheries. The offshore fisheries take place in the winter time and by assumption in the model the offshore driftnet fishery occurs in October and the longliners in December. In the spring time, the mature salmon start their spawning migration towards their home rivers. Then, the homing fish are harvested by coastal driftnet (CDN) and coastal trapnet (CTN) fisheries in the Bothnian Sea and in the Bothnian Bay. Finland and Sweden are the only countries participating in the coastal fisheries. Finally, the salmon is harvested by river fisheries, which are mainly recreational. These catches are accounted for in the biological part of the model by being deducted to the number of spawners. However, the economic value of these river fisheries has not been included in the model, which only accounts for the value of commercial fisheries. The option to concentrate on the value of commercial fisheries is due to two motives. First, the economic value of river fisheries is mainly composed of recreational benefits, which are non-market values. Estimating it, through appropriate valuation methods, is beyond the scope of this paper. Secondly, the annual TAC set under the framework of European Union's Common Fisheries Policy only refers to commercial fisheries.

Table 1 illustrates the fleet structure of each country and its different target salmon stocks. The population dynamics model considers the life history of 15 naturally reproducing salmon stocks, two of which are located in Finland (rivers Tornionjoki and Simojoki) and the remainder in Sweden. The migration route of salmon is dependent on the location of their home rivers. Therefore, it affects the stock available for each geartype and country. In addition, the model considers the life cycle of hatchery-reared salmon and their contribution to the salmon catches. These facts are encompassed on the economic part of the model that assesses each country's net present value from the fishery. The model considers the years 1995-2005. Thus, it allows us to compare the actual performance of the fishery with those that could have occurred under alternative economically sound fishing policies.

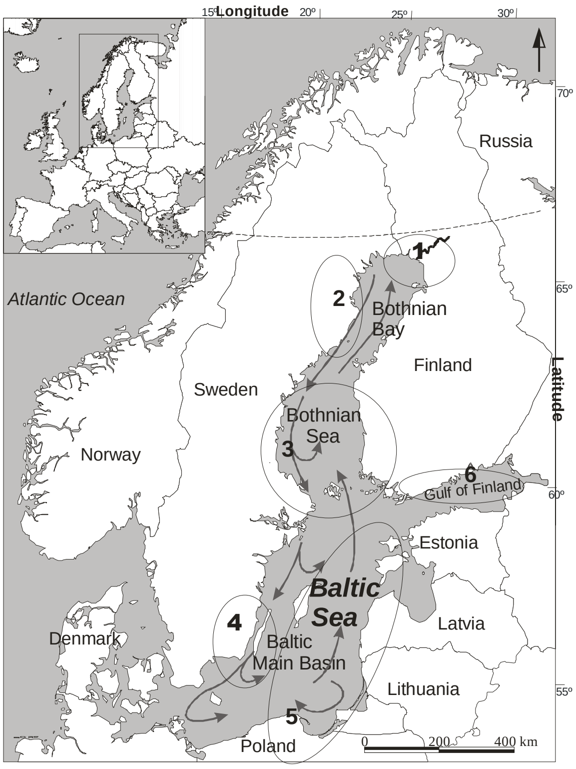

Figure 1 *Migration routes of salmon (arrows) and the grouping of salmon stocks in 6 assessment units in the Baltic Sea.*

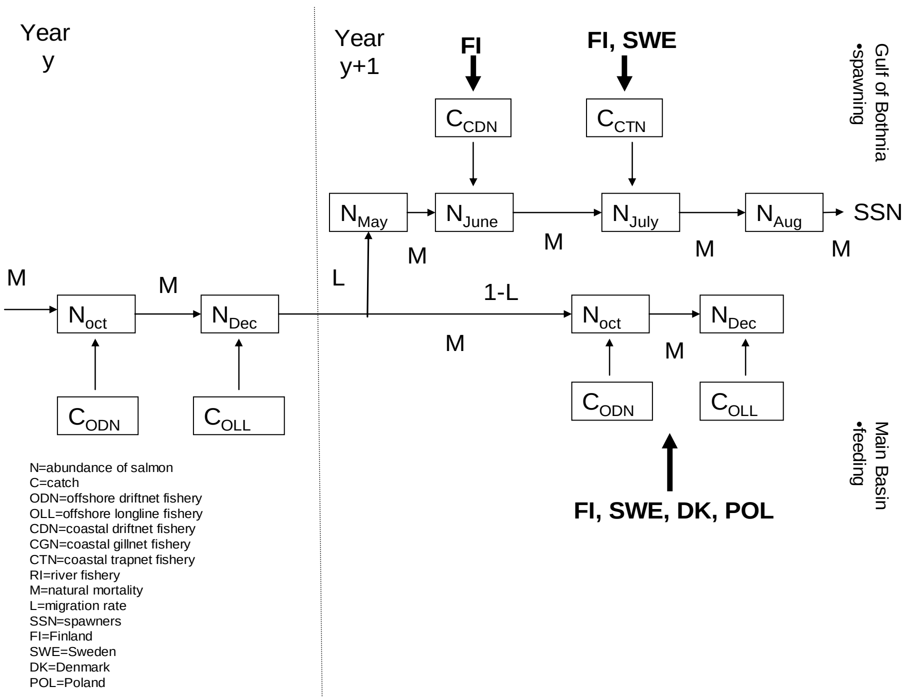

Figure 2 *Schematic presentation of the bioeconomic model.*

Table 1 *Wild salmon stocks and the fleet structure of the four countries.*

			OLL & ODN	(MB)			CDN	CTN			
	Salmon stock	**Assesment unit**	**FI**	**SWE**	**DK**	**POL**	**FI**	**FI (BS)**	**FI (BB)**	**SWE (BS)**	**SWE (BB)**
1	Tornionjoki	1	X	X	X	X	X	X	X		
2	Simojoki	1	X	X	X	X	X	X	X		
3	Kalixälven	1	X	X	X	X	X	X	X		
4	Råneälven	1	X	X	X	X	X	X	X		
5	Piteälven	2	X	X	X	X	X	X			X
6	Åbyälven	2	X	X	X	X	X	X			X
7	Byskeälven	2	X	X	X	X	X	X			X
8	Rickleån	2	X	X	X	X	X	X			X
9	Sävarån	2	X	X	X	X	X	X			X
10	Ume/Vindelälven	2	X	X	X	X	X	X			X
11	Öreälven	2	X	X	X	X	X	X			X
12	Lögdeälven	2	X	X	X	X	X	X			X
13	Ljungan	3	X	X	X	X	X	X		X	
14	Mörrumsån	4	X	X	X	X					
15	Emån	4	X	X	X	X					

3 Coalition Formation Game

In this section we define a two-stage partition function game in order to understand the strategic interaction between Finland, Sweden, Denmark and Poland. We study the coalition formation of these countries by applying a simultaneous-move and open-membership game. For instance, Pintassilgo (2003) and Pintassilgo and Lindroos (2008) have adopted the same approach in addressing straddling fish stocks. The game consists of two stages. In the first, players decide whether to behave as singletons or to join a coalition. We adopt the assumption of only one non-trivial (non-singleton) coalition (see e.g. Eyckmans and Finus 2004). Therefore, each player can only choose to play as a singleton or to join the coalition. In the second stage, singleton(s) and coalition play non-cooperatively by choosing the fishing effort strategies that maximise their payoffs, given the behaviour of the others. The game is solved by backward induction for the Nash equilibrium coalition structure.

3.1 Partition Function

Throughout the paper we follow the definitions and notation of Eyckmans and Finus (2004). We denote our coalition game between the n (= 4) players by $\Gamma(N,\pi)$. A coalition S is defined as a subset of the set of players $N=\{1,...,n\}$ and the set of all possible coalitions of N is represented by 2^N. The analysis is restricted to coalition structures consisting of only one non-trivial coalition S, with all other players $j \in N \backslash S$ being singletons[1]. Therefore, each coalition structure is fully characterized by coalition *S*. We define a restricted partition function π that assigns a single real number $\pi_S(S)$ to coalition *S* and real numbers $\pi_j(S)$ to each singleton coalition as:

$$\pi : S \mapsto \pi(S) = \left(\pi_S(S), \pi_j(S)\right) \in \mathbb{R}^{1+(n-s)} \quad \text{with} \quad j \in N \backslash S. \tag{1}$$

The domain of the restricted partition function is the set of all possible coalitions$\left(2^N\right)$. The image of this mapping is a vector with variable size, $\left(1+(n-s)\right)$ where s is the number of players in the coalition (cardinality of coalition *S*).

Since we are interested in analysing the players' incentives to form coalitions, we need to define how each player values the coalitions. Therefore, we define a valuation function v to each coalition that prescribes how the worth of coalition S is allocated among its members. A valuation function assigns to every coalition S of N a real-valued vector of length n , $v: 2^N \to \mathbb{R}^n: S \mapsto v(S)$, such that:

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[1] *This approach is, therefore, a special case of the general definition of partition functions defined for instance by Bloch (2003).*

(2) $$\begin{cases} \sum_{i\in S} v_i(S) = \pi_S(S) \\ \quad v_j(S) = \pi_j(S) \quad \forall j \in N\backslash S. \end{cases}$$

Valuations $v_i(S)$ satisfies group rationality, meaning that the entire worth of coalition *S*, $\pi_S(S)$, is allocated to its members. For each singleton, the valuation $v_j(S)$ coincides with the worth $\pi_j(S)$ assigned by the partition function. As equation (2) shows the valuation specifies the payoff for the coalition members and the singletons and does this for all possible coalitions. Therefore, for any coalition structure, each player is able to evaluate its gains compared to full non-cooperation. Consequently, a valuation fixes the sharing rule of the cooperative surplus that is the excess of the coalition payoff over the sum of its players' payoffs under full non-cooperation.

3.2 Attributes of the game

Let us now define formally the concepts of positive externalities, superadditivity and global efficiency. These attributes of the game play an important role in determining if the grand-coalition is stable and whether the economic and biological benefits of the cooperation between Finland, Sweden, Denmark and Poland, suggested by Kulmala et al. (2009), would be realised.

A coalition game $\Gamma(N,\pi)$ exhibits positive externalities if and only if its partition function π satisfies: $\forall S \subseteq N, \forall j \neq i, j \notin S : \pi_j(S) \geq \pi_j(S\backslash\{i\})$.[2] Positive externalities imply that the remaining singletons do not lose when coalitions merge.

A coalition game $\Gamma(N,\pi)$ is superadditive if and only if its partition function π satisfies: $\forall S \subseteq N, \forall i \in S : \pi_S(S) \geq \pi_{S\backslash\{i\}}(S\backslash\{i\}) + \pi_i(S\backslash\{i\})$. Superadditivity implies that that the value of the coalition must be at least the value of the coalition when one player deviates plus the payoff of the deviator after deviation. Thus, superadditivity implies that a merger does not decrease the aggregate welfare of the merging players.

Finally, we say that a coalition game $\Gamma(N,\pi)$ is globally efficient if and only if:

$$\forall S \subset N, \forall i \in N\backslash S : \pi_S(S\cup\{i\}) + \sum_{j\in N\backslash(S\cup\{i\})} \pi_j(S\cup\{i\}) \geq \pi_S(S) + \sum_{j\in N\backslash S} \pi_j(S).$$

Thus, if a partition function is superadditive the grand coalition is always the most efficient coalition structure. However, if the game is both superadditive and exhibits positive externalities, the grand coalition may not be stable. That happens if the free rider incentives due to the positive externalities exceed the superadditivity effect.

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[2] *Eyckmans and Finus (2004) define positive externalities:* $\forall S \subseteq N, \forall j \neq i, j \notin S : \pi_j(S) \geq \pi_j(S\backslash\{i\})$ *and* $\exists k \neq i, k \notin S : \pi_k(S) > \pi_k(S\backslash\{i\})$. *However, their results are robust to our more loose definition that considers also the neutral effects of coalition formation.*

3.3 Stability Concept

We adopt the definition for stable coalition due to D'Aspremont et al. (1983). According to it coalition S is considered to be stable with respect to the valuations $v(S)$ if and only if S is both internally and externally stable. A coalition game $\Gamma(N,\pi)$ is internally stable (IS) if and only if: $\forall i \in S : v_i(S) \geq v_i(S \backslash \{i\})$. Internal stability implies that no coalition member finds it optimal to leave the coalition[3]. A coalition game $\Gamma(N,\pi)$ is externally stable (ES) if and only if: $\forall j \in N \backslash S : v_j(S) \geq v_j(S \cup \{j\})$. External stability (ES) implies that no singleton finds it optimal to join the coalition. As defined earlier, the valuation function specifies how the worth of coalition S is allocated among its members. Therefore, as there are several valuation functions that can be derived from a single partition function, a coalition S may be stable with respect to a particular valuation function but not be with respect to another.

[3] *Since the paper focus on only one non-trivial coalition, internal stability coincides with the stand alone stability defined by Yi (1997). According to it, a coalition structure is stand-alone stable if no player finds it optimal to leave its coalition to form a singleton coalition, holding the rest of the coalition structure constant.*

4 Restricted effort strategies

The present section presents the results of the coalition formation game that is constructed to reflect fisheries policy under RSP[4]. The objective of the coalition members is to maximise the sum of their net present value (NPV) from the salmon fishery given that the players outside the coalition also maximize their NPV. The maximisation of the coalition is, however, constrained by the restriction that all coalition members harvest and adopt the same proportional change to the fishing efforts reported in the period 1995-2005 (ICES 2008). Throughout the paper, it is assumed that the strategy space of each country is bounded below by zero and upper by the fishing strategy that the country would adopt if it were the sole exploiter of the stock (see e.g. Arnason et al. 2000). The strategy of country k is defined as: $X_{k,t} = \frac{E_{k,t}}{E^{rep}_{k,t}}, X_{k,t} \in \left[0, \bar{X}_k\right]$, where $X_{k,t}$ represents the ratio of country's k fishing effort in year $t \left(E_{k,t}\right)$ to its reported fishing effort $\left(E^{rep}_{k,t}\right)$; and $\bar{X}_k$ the upper bound of this ratio.

Table 2 illustrates the partition function $\pi\left(S\right)$ and valuation function $v\left(S\right)$ for each coalition structure. The partition function assigns a payoff for the coalition, $\pi_S\left(S\right)$, and for the singletons, $\pi_j\left(S\right), \forall j \in N \backslash S$. The valuation function also indicates the payoff each coalition member gets, $v_{i\in S}\left(S\right)$, which in this case corresponds to their own fishing effort, as transfers between coalition members are not considered. Except for the singleton coalition structure, the value of the coalition $\pi_S\left(S\right)$ is shown in shaded. Coalition structures 3, 4 and 7 produced several Nash equilibrium for the fishing effort strategies. We considered all as equally likely and therefore used the corresponding expected values for the fishing effort strategies and payoffs.

The results show that the merger of coalitions increases the payoff of the non-merging players, for example when Finland and Sweden form a coalition (2) the payoffs of Denmark and Poland increases. Consequently, the game exhibits positive externalities. However, the results show that the game is not superadditive. That can be easily verified for instance by looking at coalition structure 2, where Finland and Sweden form a coalition. The value of the two player coalition (5149) is less than the sum of the payoffs the two players would get if the coalition would break apart (6035, under coalition structure 1). Further, although the merger of coalitions generally increases the aggregate payoffs there are exceptions. Thus, the game is also not globally efficient.

Finally, the results show that cooperation among the four countries is not stable. Furthermore, the only stable coalition structure is full non-cooperation, where all the players are singletons[5]. These results help to explain why the cooperation among the

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[4] *The results show the partition function of the "Cooperation A" scenario analyzed in Kulmala et al. (2009).*

[5] *In our game the coalition structure formed only by singletons is stable by definition because it can be generated by $S = \emptyset$, that is all players announce not to join the agreement. This coalition structure is internally stable as no player can withdraw and also externally stable because if only one player changes its announcement the coalition structure remains the same.*

fishing states, under the auspices of the European Union, seems to be trivial. In fact, according to the results, the fishing efforts under full cooperation should be 40% lower that what has been effectively reported by the four countries. Furthermore, we can conclude that reported fishing effort strategies by the two major players of the game, Finland and Sweden, are close to the ones under full non-cooperation (coalition structure 1). Thus, it can be argued that the management of the salmon stocks in the Baltic Sea, from 1995 to 2005, resembles the case of full non-cooperation. In the next section we assess the prospects of effective cooperation under more flexible fishing strategies and sharing schemes.

Table 2 *Partition and value functions in thousand's of euros (t€) for the proportional shares strategies.*

	Coalition (S)		*Finland* 1	*Sweden* 2	*Denmark* 3	*Poland* 4	total	*IS*	*ES*
		strategy	0.9	1.05	0.45	1.35			
		v(S)	4101	1934	170	1451			
1	**(1),(2),(3),(4)**	**π(S)**	4101	1934	170	1451	**7656**	**yes**	**yes**
		strategy	0.6	0.6	0.9	1.5			
		v(S)	3631	1518	577	1792			
2	**(1,2), (3), (4)**	**π(S)**	5149		577	1792	**7518**	no	yes
		E[strategy]	0.6	1.125	0.6	1.425			
		E[v(S)]	3425	2317	302	1609			
3	**(1,3), (2), (4)**	**E[π(S)]**	3728	2317		1609	**7654**	no	yes
		E[strategy]	0.675	1.425	1.275	0.675			
		E[v(S)]	4166	3765	1344	919			
4	**(1,4), (2), (3)**	**E[π(S)]**	5086	3765	1344		**10194**	no	yes
		strategy	0.9	0.6	0.6	1.5			
		v(S)	4241	1275	248	1640			
5	**(2,3), (1), (4)**	**π(S)**	4241	1523		1640	**7404**	no	yes
		strategy	0.9	0.75	1.35	0.75			
		v(S)	5258	2330	1577	1066			
6	**(2,4), (1), (3)**	**π(S)**	5258	3395	1577		**10231**	no	yes
		E[strategy]	0.975	1.425	0.6	0.6			
		E[v(S)]	5545	4078	760	867			
7	**(3,4), (1), (2)**	**E[π(S)]**	5545	4078	1627		**11251**	no	yes
		strategy	0.6	0.6	0.6	1.5			
		v(S)	3904	1713	525	1927			
8	**(1,2,3), (4)**	**π(S)**		6142		1927	**8069**	no	yes
		strategy	0.6	0.6	1.95	0.6			
		v(S)	4598	2372	3217	979			
9	**(1,2,4), (3)**	**π(S)**	7950		3217		**11166**	no	yes
		strategy	0.6	1.65	0.6	0.6			
		v(S)	4561	5547	994	963			
10	**(1,3,4), (2)**	**π(S)**	6518	5547			**12065**	no	yes
		strategy	1.05	0.6	0.6	0.6			
		v(S)	7376	2651	1242	1065			
11	**(2,3,4), (1)**	**π(S)**	7376		4957		**12333**	no	yes
		strategy	0.6	0.6	0.6	0.6			
		v(S)	6083	3434	1745	1269			
12	**(1,2,3,4)**	**π(S)**		12530			**12530**	no	yes

5 Optimal effort strategies

The present section presents the results of the coalition formation game when each coalition adopts optimal fishing efforts for its members[6]. Table 3 presents the partition function of the game. As expected, the coalition payoffs $\pi_S\left(S\right)$, shown in shaded, have increased relative to the previous scenario, whereas the outcome of the singleton coalition structure (1) remained unchanged. The results show that similarly to the restricted effort case the present game exhibits positive externalities. Further, when departing from full non-cooperation (1) to the grand-coalition (12) the aggregate payoff increases from 7.7 million euros to 17.2 million euros. The same applies to all mergers and therefore the game is globally efficient.

However, the game is not superadditive, that is, there are mergers that decrease the aggregate payoff of the players involved. There are three cases when superadditivity fails. For instance, under coalition structure 2, the payoff of the coalition formed by Finland and Sweden is lower than the sum of the payoffs that these countries would get if the coalition would break apart. As Eyckmans and Finus (2004) show, through a survey of coalition games, the violation of superadditivity is not unusual in games in partition function form. Moreover, in fishery games, the violation of superadditivity is also common, even using simple bioeconomic models (e.g. the classical Gordon-Schaefer model used in Pintassilgo et al. (2008), for some parameter values). One of the reasons why superadditivity fails, termed as the "leakage effect", is that, in the presence of a merger, singletons tend to increase their fishing efforts as a reaction to the reduction of the total fishing effort of the players involved in the merger.

Having analysed fundamental characteristics of the game, let us now study the stability of all possible coalitions. In this section we allow for transfers between coalition members. Thus, let us introduce the concept of potential internal stable coalition. According to Eyckmans and Finus (2004), a coalition *S* is potentially internally stable (PIS) for partition function π if and only if: $\pi_S\left(S\right)\geq\sum_{i\in S}\pi_i\left(S\backslash\{i\}\right)$, i.e. the value of the coalition is at least equal to the sum of the free rider payoffs. The free-rider payoff is defined as the payoffs of a coalition member that leaves it to become a singleton, holding the rest of the coalition structure unchanged. Table 3 shows that the present game, in addition to the singleton coalition structure, has five potentially internally stable coalition structures (3-7), all with two-player-coalitions.

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[6] *The results show the partition function of the "Cooperation B" scenario analyzed in Kulmala et al. (2009).*

Table 3 *Partition function in thousand's of euros (t€) for the optimal strategies scenario.*

	Coalition (S)		*Finland* 1	*Sweden* 2	*Denmark* 3	*Poland* 4	total	*PIS*
		strategy	0.9	1.05	0.45	1.35		
1	(1),(2),(3),(4)	π(S)	4101	1934	170	1451	**7656**	yes
		strategy	0.75	0.45	0.75	1.5		
2	(1,2), (3), (4)	π(S)	5421		506	1807	**7734**	no
		E[strategy]	0.90	1.13	0	1.43		
3	(1,3), (2), (4)	E[π(S)]	4328	2225		1591	**8144**	yes
		strategy	1.05	1.5	1.65	0		
4	(1,4), (2), (3)	π(S)	5922	4630	2419		**12971**	yes
		E[strategy]	0.90	1.13	0	1.43		
5	(2,3), (1), (4)	E[π(S)]	4328	2225		1591	**8144**	yes
		strategy	1.05	1.5	1.65	0		
6	(2,4), (1), (3)	π(S)	5922	4630	2419		**12971**	yes
		strategy	1.05	1.5	1.65	0		
7	(3,4), (1), (2)	π(S)	5922	4630	2419		**12971**	yes
		strategy	0.75	0.75	0	1.5		
8	(1,2,3) (4)	π(S)	6776			1963	**8739**	no
		strategy	0.75	1.05	2.25	0		
9	(1,2,4) (3)	π(S)	9927		4436		**14363**	no
		strategy	0.9	1.8	0.75	0		
10	(1,3,4) (2)	π(S)	8316	7109			**15425**	no
		E[strategy]	1.125	1.875	0	0		
11	(2,3,4) (1)	E[π(S)]	7988	7766			**15754**	no
		strategy	0.75	1.5	0	0		
12	(1,2,3,4)	π(S)	17187				**17187**	no

We now turn to the sharing of the gains from cooperation. We consider the Almost Ideal Sharing Scheme (AISS) suggested by Eyckmans and Finus (2004). They showed that the AISS stabilizes the PIS coalition that has the highest aggregate worth and therefore that sharing scheme can be regarded as optimal. Further, this result is robust with respect to the surplus allocation, i.e. it does not depend on the sharing weights. Eyckmans and Finus (2004) define the Almost Ideal Valuation Function (AIVF) for coalition game $\Gamma(N,\pi)$ as a valuation function $v^{AIVF(\lambda)}$ that satisfies:

$$\forall S \subseteq N : \begin{cases} \forall i \in S : v_i^{AIVF(\lambda)}(S) = \pi_i\left(S \backslash \{i\}\right) + \lambda_i(S)\sigma(S) \\ \forall j \in N \backslash S : v_j^{AIVF(\lambda)}(S) = \pi_j(S) \end{cases}$$

with $\lambda(S) \in \Delta^{s-1} = \left\{\lambda \in \mathbb{R}_+^s \mid \sum_{j \in S} \lambda_j = 1\right\}$, where Δ^{s-1} denotes the set of all possible sharing weights of a coalition with s players, and $\sigma(S)$ the coalition surplus, $\sigma(S) = \pi_S(S) - \sum_{i \in S} \pi_i\left(S \backslash \{i\}\right)$, which can be positive, negative or nil. Consequently, an AIVF allocates to each coalition member its free-rider payoff plus some share, $\lambda(S)$, of the surplus. We illustrate the AISS by using equal weights i.e. $\lambda_i(S) = \frac{1}{s}, \forall S \subseteq N, \forall i \in S.$

Table 4 presents the stability analysis of the present game. The results show that the AISS stabilizes all the PIS coalitions. Further, the three coalition structures with the highest aggregate payoff (4, 6 and 7) have Poland as a member. It can also be noted that no coalition where both Finland and Sweden are present is stable. Stable cooperation can only be achieved through two-player coalitions. However, these coalitions lead to substantial economic benefits when compared to full non-cooperation.

Table 4 *Valuation functions for the optimal effort strategies with the Almost Ideal Sharing Scheme (AISS).*

	Coalition (S)		*AISS* Finland	Sweden	Denmark	Poland	*total*	*IS*	*ES*
		share							
1	**(1),(2),(3),(4)**	**v(S)**	4101	1934	170	1451	7656	**yes**	**yes**
		share	0.70	0.30					
2	**(1,2), (3), (4)**	**v(S)**	3794	1627	506	1807	7734	no	yes
		share	0.95		0.05				
3	**(1,3), (2), (4)**	**v(S)**	4129	2225	198	1591	8144	**yes**	**yes**
		share	0.72			0.28			
4	**(1,4), (2), (3)**	**v(S)**	4286	4630	2419	1636	12971	**yes**	**yes**
		share		0.90	0.10				
5	**(2,3), (1), (4)**	**v(S)**	4328	1994	231	1591	8144	**yes**	**yes**
		share		0.55		0.45			
6	**(2,4), (1), (3)**	**v(S)**	5922	2556	2419	2074	12971	**yes**	**yes**
		share			0.24	0.76			
7	**(3,4), (1), (2)**	**v(S)**	5922	4630	569	1850	12971	**yes**	**yes**
		share	0.62	0.31	0.06				
8	**(1,2,3), (4)**	**v(S)**	4234	2131	411	1963	8739	no	yes
		share	0.51	0.38		0.10			
9	**(1,2,4), (3)**	**v(S)**	5111	3819	4436	996	14363	no	yes
		share	0.65		0.23	0.13			
10	**(1,3,4), (2)**	**v(S)**	5384	7109	1880	1052	15425	no	yes
		share		0.56	0.27	0.17			
11	**(2,3,4), (1)**	**v(S)**	7988	4339	2127	1300	15754	no	yes
		share	0.40	0.35	0.20	0.05			
12	**(1,2,3,4)**	**v(S)**	6911	6032	3359	886	17187	no	yes

6 Implications for salmon stocks

Given the differences in the fleet structure of each country and the migration route of salmon stocks, it is relevant to assess the status of the salmon stocks under the different coalition structures. We examine the following coalition structures: full non-cooperation (1), the stable coalition structures with two-player coalitions (3&5, and 4&6&7), and the grand-coalition under both the optimal effort strategies (12 opt.) and the restricted effort strategies (12 res.). Figure 3 illustrates the smolt production of six salmon rivers and the respective biological management objective, that is, to reach 50% of the smolt production capacity, by the year 2010. The rivers in the upper part of the figure, Tornionjoki, Simojoki, and Råneälven, belong to the assessment unit 1, rivers Sävarån and Lögdeälven belong to the assessment unit 2, and river Emån to the assessment unit 4 (see Table 1).

The results show that the stable cooperative coalition structures produce significantly lower number of smolts than the grand coalition, in both the restricted and optimal effort cases. Further the performance of stable coalitions, in terms of number of smolts, is closer to non-cooperation than to the grand coalition. Consequently, the biological management objectives cannot be reached with stable coalitions. However, in economic terms there are significant gains for departing from non-cooperation to a stable coalition (see Table 3).

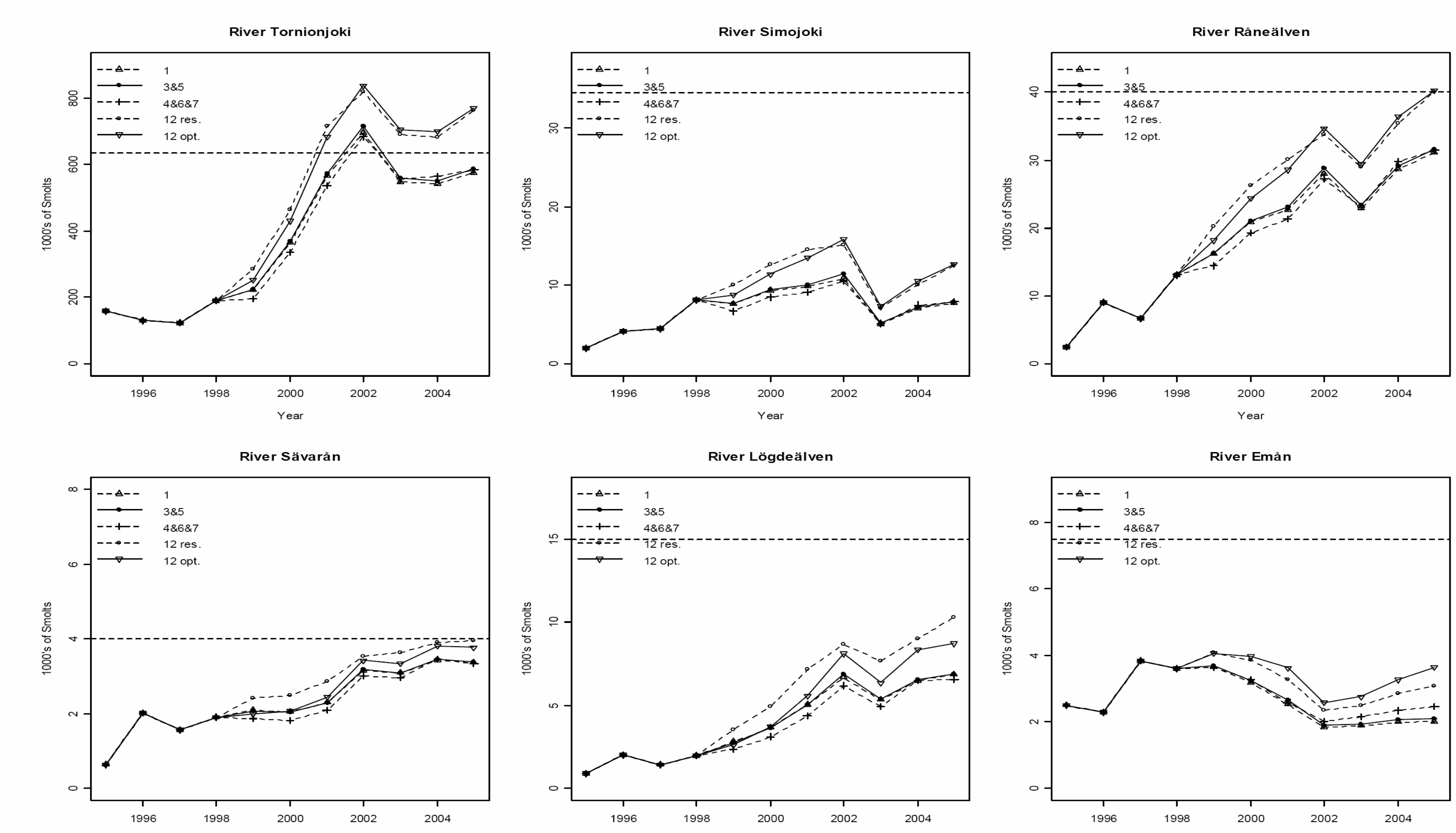

Figure 3 *The number of smolts per river under different coalition structures. The horizontal dotted line shows the 50% of the estimated mean carrying capacity (ICES 2008 p. 255).*

7 Conclusions

The Atlantic salmon fishery in the Baltic Sea has shown clear signs of biological and economic over-exploitation, over the last two decades. Although, all the Baltic Sea riparian countries, except Russia, are members of the European Union and agree on the annual fishing possibilities under the Common Fisheries Policy (CFP) the salmon quota has not restricted the fishery. The catches year after year below TACs suggest that cooperation under the CFP framework has been trivial.

Using a game in the partition function form, we show that, in fact, cooperation between the countries that are responsible for nearly 90% of the salmon catch is not a stable outcome. On the contrary, the equilibrium of the game is full non-cooperation if the fishing strategies are in accordance with the Relative Stability Principle (RSP). Moreover, in this equilibrium the fishing strategies of the two major players, Finland and Sweden, are close to what has been effectively reported by them. Thus, the actual management of the salmon stocks in the Baltic Sea resembles the case of full non-cooperation. We also investigated the consequences of relaxing the RSP by allowing each coalition member to adopt its optimal strategy. The results show that the presence of positive externalities makes cooperation elusive. However, an appropriate sharing rule, AISS, is able to stabilize two-player-coalitions. It is found that in all stable coalition structures, with the highest aggregate payoff, Poland is a coalition member. Further, we found that any cooperative agreement that includes Finland and Sweden, the two countries where the reproduction areas of this anadromous species are located, is not stable.

The results show that substantial economic benefits could have been realised by reallocating the fishing effort, but the biological management objectives could not have been reached with stable coalitions. The present analysis considered the period 1995-2005. Due to the life cycle of salmon, a longer period would be needed in order for stable coalitions to produce significant biological benefits.

Some of results obtained are significantly different from those obtained by Pintassilgo and Lindroos (2008). Using the classical Gordon-Schaefer bioeconomic model in a symmetric player setting, the authors concluded that the only stable coalition structure is the one formed by singletons, that is, complete non-cooperation. Hence, our results indicate that by allowing for asymmetric players and considering disaggregated bioeconomic models it is possible to guarantee higher levels of cooperation. Extending the present empirical model opens several possibilities for further research, namely studying the stability of coalitions over time and the role of uncertainty in coalition formation.

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References

Aps R, Kell LT, Lassen H, Liiv I (2007) Negotiation Framework for Baltic Fisheries Management: Striking the Balance of Interest. ICES J Mar Sci 64(4):858-861.

Arnason R, Magnusson G, Agnarsson S (2000) The Norwegian Spring-Spawning Herring Fishery: A Stylized Game Model. Mar Resour Econ 15:293-319.

Bloch F (2003) Non-Cooperative Models of Coalition Formation in Games with Spillovers.In: Carraro C (ed) Endogeneous Formation of Economic Coalition. Edwar Elgar, Cheltenhamn, UK.

Boude J, Boncoeur J, Bailly D (2001) Regulating the Access to Fisheries: Learning from European Experiences. Marine Policy, 25(4):313-322.

Council Regulation (EEC) No 172/83 of 25 January 1983. Official Journal L 024 , 27/01/1983, pp. 30–67.

D'Aspremont C, Jacquemin A, Gabszewicz JJ, Weymark JA (1983) On the Stability of Collusive Price Leadership. The Canadian Journal of Economics 16(1):17-25.

Duarte CC, Brasao A, Pintassilgo P (2000) Management of the Northern Atlantic Bluefin Tuna: An Application of C-Games. Mar Resour Econ 15(2000):21-36.

European Commission (2007) Open Call for Tenders. Reference No FISH/2007/03. Studies and Pilot Projects for Carrying Out the Common Fisheries Policy (6 lots). Tendering Specifications.Directorate-General for Fisheries And Maritime Affairs,http://ec.europa.eu/fisheries/press_corner/calls/2007_03/specifications_en.pdf.

Eyckmans J, Finus M (2004) An Almost Ideal Sharing Scheme for Coalition Games with Externalities. Fondazione Eni Enrico Mattei, Working Paper (155.04).

FGFRI (Finnish Game and Fisheries Research Institute) (2009) Data Analysis to Support the Development of a Baltic Sea Salmon Managment Plan, Helsinki. http://www.rktl.fi/www/uploads/Seminaarit/tutkimusseminaari030209raportti.pdf

Gordon HS (1954) The Economic Theory of a Common-Property Resource: The Fishery. Journal of Political Economy 62(2):124.

ICES (2008) Report of the Baltic Salmon and Trout Working Group (WGBAST), 1-10 April 2008. Gdynia, Poland.

---. (2007) Report of the Baltic Salmon and Trout Working Group (WGBAST), 11-20 April 2007. Vilnius, Lithuania.

Jokikokko E, Kallio-Nyberg I, Jutila E (2004) The Timing, Sex and Age Composition of the Wild and Reared Atlantic Salmon Ascending the Simojoki River, Northern Finland. J Appl Ichthyol 20(1):37-42.

Kaitala V, Lindroos M (1998) Sharing the Benefits of Cooperation in High Seas Fisheries: A Characteristic Function Game Approach. Natural Resource Modeling 11(4):87-108.

Kallio-Nyberg I, Jutila E, Saloniemi I, Jokikokko E (2004) Association Between Environmental Factors, Smolt Size And the Survival of Wild and Reared Atlantic Salmon from the Simojoki River in the Baltic Sea. J Fish Biol 65(1):122-134.

Karlsson L, Karlström Ö (1994) The Baltic Salmon (Salmo salar L.): Its history, Present Situation and Future. Dana (10):61-85.

Koljonen ML, Jansson H, Paaver T, Vasin O, Koskiniemi J (1999) Phylogeographic Lineages and Differentiation Pattern of Atlantic Salmon (Salmo salar) in the Baltic Sea with Management Implications. Can J Fish Aquat Sci 56(10):1766-1780.

Kulmala S, Levontin, P, Lindroos M, Michielsens CGJ, Pakarinen T, Kuikka S (2009) International Management of the Atlantic Salmon Fishery in the Baltic Sea. Manuscript submitted in 2009. An earlier version is available at: http://www.mm.helsinki.fi/mmtal/abs/DP22.pdf

Kulmala S, Laukkanen M, Michielsens CGJ (2008) Reconciling Economic and Biological Modeling of Migratory Fish Stocks: Optimal Management of the Atlantic Salmon Fishery in the Baltic Sea. Ecological Economics, 64(4):716-728.

Laukkanen M (2003) Cooperative and Non-Cooperative Harvesting in a Stochastic Sequential Fishery. Journal of Environmental Economics and Management, 45(2, Supplement 1):454-473.

---. (2001) A Bioeconomic Analysis of the Northern Baltic Salmon Fishery: Coexistence versus Exclusion of Competing Sequential Fisheries. Environmental and Resource Economics 18(3):293-315.

Lindroos M (2004) Sharing the Benefits of Cooperation in the Norwegian Spring-Spawning Herring Fishery. International Game Theory Review 6(1):35–53.

Michielsens CGJ, Murdoch KM, Sakari K, Samu M, Atso R, Tapani P, Lars K, Laura U (2008) Combining Multiple Bayesian Data Analyses in a Sequential Framework for Quantitative Fisheries Stock Assessment. Can J Fish Aquat Sci 65:962-974.

Pham Do K, Folmer H (2006) International Fisheries Agreements: the Feasibility and Impacts of Partial Cooperation.In: Aronsson T, Axelsson R, Brännlund R (eds) The Theory and Practice of Environmental And Resource Economics : Essays in Honour of Karl-Gustaf Löfgren. Edward Elgar, Cheltenham, UK Northampton, MA.

Pintassilgo P, Lindroos M (2008) Coalition Formation in Straddling Stock Fisheries: A Partition Function Approach. International Game Theory Review 10(3):303-317.

Pintassilgo P (2003) A Coalition Approach to the Management of High Seas Fisheries in the Presence of Externalities. Nat Resour Model 16(2):175-197.

Romakkaniemi A, Pera I, Karlsson L, Jutila E, Carlsson U, Pakarinen T (2003) Development of Wild Atlantic Salmon Stocks in the Rivers of the Northern Baltic Sea in Response to Management Measures. ICES J Mar Sci 60(2):329-342.

Säisä M, Koljonen ML, Gross R, Nilsson J, Säisä M, Koskiniemi J, Vasemagi A (2005) Population Genetic Structure and Postglacial Colonization of Atlantic Salmon (Salmo salar) in the Baltic Sea Area Based on Microsatellite DNA variation. Can J Fish Aquat Sci 62(8):1887-1904.

Säisä M, Koljonen ML, Tähtinen J (2003) Genetic Changes in Atlantic Salmon Stocks Since Historical Times And the Effective Population Size of a Long-Term Captive Breeding Programme. Conserv Genet 4(5):613-627.

Schaefer MB (1957) Some Considerations of Population Dynamics and Economics in Relation to the Management of the Commercial Marine Fisheries. Journal of the Fisheries Research Board of Canada 14(5):669-681.

Uusitalo L, Kuikka S, Romakkaniemi A (2005) Estimation of Atlantic Salmon Smolt Carrying Capacity of Rivers Using Expert Knowledge. ICES J Mar Sci 62(4):708.

Yi S (1997) Stable Coalition Structures with Externalities. Games and Economic Behavior, 20(2):201-237.